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(54) Title: PN CODE SELECTION FOR SYNCHRONOUS CDMA

(57) Abstract

A method for improving the spectral properties of a PN codeset for use in channels of a synchronous CDMA telecommunications system. The method includes steps of (a) providing a PN codeset matrix; and (b) reordering the columns of the PN codeset matrix in accordance with a reordering code. The method may further include the step of inverting at least one code word of the reordered PN codeset in accordance with an inversion pattern, and may further include the step of selecting PN codes to optimize a subset of channels to operate in an asynchronous manner.

$$Reordering\_code = [3 \quad 5 \quad 2 \quad 7 \quad 1 \quad 8 \quad 4 \quad 6]$$

$$Walsh\_code = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \end{bmatrix}$$

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PN CODE SELECTION FOR SYNCHRONOUS CDMA

CLAIM OF PRIORITY FROM A COPENDING PROVISIONAL PATENT APPLICATION:

Priority is herewith claimed under 35 U.S.C. §119(e) from copending Provisional Patent Application 60/091,070, filed 6/29/98, entitled "PN CODE SELECTION FOR SYNCHRONOUS CDMA", by Leon Nieczyporowicz, Thomas Giallorenzi and Steven Perkins. The disclosure of this Provisional Patent Application is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION:

This patent application relates generally to digital radio telecommunications systems and, in particular, to synchronous Code Division Multiple Access (CDMA) telecommunications that employ pseudonoise (PN) spreading codes, such as Hadamard or Walsh codes.

BACKGROUND OF THE INVENTION:

In synchronous CDMA systems the PN codeset that is typically used to differentiate users is the Walsh set. However, the Walsh codeset has poor spectral properties and, as a result, it is desirable to provide some randomization of the codeset. It is known in the art to scramble the Walsh code by generating another PN code, i.e., a "cover code", of the same length as the Walsh code,

of inverting at least one codeword of the reordered PN codeset in accordance with an inversion pattern, and may further include the step of selecting PN codes to optimize a subset of channels to operate in an asynchronous manner.

BRIEF DESCRIPTION OF THE DRAWINGS

The above set forth and other features of the invention are made more apparent in the ensuing Detailed Description of the Invention when read in conjunction with the attached Drawings, wherein:

Fig. 1 is a simplified block diagram of a synchronous, spread spectrum CDMA fixed wireless communications system in accordance with an embodiment of this invention, the system having a radio base unit (RBU) and a plurality of transceiver or subscriber units (SUs). The RBU transmits a side channel to the SUs, and also receives an essentially asynchronously transmitted side channel from the SUs.

Fig. 2 is an exemplary frequency allocation diagram of the system of Fig. 1.

Fig. 3A illustrates an exemplary Hadamard (H) matrix, Fig. 3B illustrates a Reordering Code (RC), and Fig. 3C illustrates a Reordered Hadamard (RH) code matrix in accordance with this invention.

Fig. 4 illustrates an exemplary 8x8 Walsh code matrix, an exemplary reordering code, and the resultant reordered Walsh code matrix, in accordance with this invention.

Fig. 5 illustrates an exemplary inversion pattern for application to the reordered Walsh code matrix of Fig. 4, and the resultant inverted, reordered Walsh code matrix, in accordance with an aspect of this invention.

(CPE). The CPE also includes a Network Termination Unit (NTU) and an Uninterruptible Power Supply (UPS), which are not illustrated in Fig. 1.

The RBU 12 includes circuitry for generating a plurality of user signals (USER_1 to USER_n), which are not shown in Fig. 1, and a synchronous side channel (SIDE_CHAN) signal that is continuously transmitted. Each of these signals is assigned a respective PN spreading code and is modulated therewith before being applied to a transmitter 12a having an antenna 12b. When transmitted on the FL the transmissions are modulated in phase quadrature, and the SUs 14 are assumed to include suitable phase demodulators for deriving in-phase (I) and quadrature (Q) components therefrom. The RBU 12 is capable of transmitting a plurality of frequency channels. By example, each frequency channel includes up to 128 code channels, and has a center frequency in the range of 2 GHz to 3 GHz.

The RBU 12 also includes a receiver 12c having an output coupled to a side channel receiver 12d. The side channel receiver 12d receives as inputs the spread signal from the receiver 12c, a scale factor signal, and a side channel despread pn code. These latter two signals are sourced from a RBU processor or controller 12e. The scale factor signal can be fixed, or can be made adaptive as a function of the number of SUs 14 that are transmitting on the reverse channel. The side channel receiver 12d outputs a detect/not detect signal to the RBU controller 12e for indicating a detection of a transmission from one of the SUs 14, and also outputs a power estimate value χ. A read/write memory (MEM) 12f is bidirectionally coupled to the RBU controller 12e for storing system parameters and other information, such as SU timing phase information and power estimate values.

Having thus described one suitable, but not limiting, technological environment wherein the teachings of this invention may be practiced, a description of the invention is now provided.

A stated object of this invention is to improve the performance and reliability of synchronous CDMA systems, such as the one described above with respect to Figs. 1 and 2. The particular concerns addressed by this invention are (a) avoiding poor spectral properties associated with the Walsh codeset, (b) avoiding system degradation due to the existence of correlated data between users, and (c) avoiding the detrimental effects of one or more channels which may be asynchronous.

In accordance with a first aspect of this invention the spectral properties of the Walsh codeset are improved by re-ordering the columns of the Walsh codeset matrix.

In the Walsh codeset matrix (whether reordered in accordance with this invention or scrambled), one column is all ones. In the normal operation of the synchronous CDMA system some correlated data may occur (e.g., a synchronization pattern, a particular silence pattern from a voice encoder, etc.). To overcome this problem, and further in accordance with this invention, some of the rows of the Walsh matrix may be inverted. This prevents the all ones column from resulting in a large correlation peak in the composite signal, which may cause a problem in the presence of non-linear impairments (i.e. clipping).

Within the reordered Walsh set the codes have different auto-correlation and cross-correlation properties. In synchronous CDMA systems there may exist an asynchronous channel (e.g., the side channel) to synchronize users who are new to the system, or those that have lost

Describing the invention now in further detail, Fig. 3A illustrates an exemplary Hadamard matrix (treating a -1 as a 0). In this regard it is noted that corresponding values stored in a memory have binary values of 1 and 0. These bits are exclusive ORed to create a 0 or 1 chip value in each chip period. It is then assumed that in the subsequent modulation stage(s) the 0 and 1 values chips are remapped to -1 and +1 valued chips.

In accordance with this invention, reordered Hadamard codes are constructed by reordering the columns of the Hadamard matrix. For example, the Hadamard matrix (H) of Fig. 3A is reordered using the Reordering Code (RC) shown in Fig. 3B, and the resulting Reordered Hadamard (RH) code matrix is shown in Fig. 3C. Note that the third column has been moved to the first column position, and columns 1 and 2 have been shifted to the right by one column position.

In this case the Reordered Hadamard becomes a time shifted Hadamard with the codes renumbered. However, for Hadamards of order 8 or higher the reordering produces completely different codesets. To generate Reordering Codes, the states of an m-sequence generator can be lengthened by placing 128 at the end of the code. Randomly generated Reordering Codes can be employed as well. For example, Fig. 6 shows a block diagram of a random number generator 16 that outputs a Reordering Pattern or Code 16a to a shift register 18 having feedback through an XOR function 20.

Examining Fig. 3C it can readily be seen that one important advantage of the use of reordered Hadamard codes, in accordance with the teachings of this invention, is that all of the codes, except the all ones code, are perfectly balanced.

If all of the transmitted signals in the CDMA system need

For a case where all of the channels in the system 10 may be transmitting the same data (e.g., a sync pattern at the beginning of a frame), the resulting waveform is the sum of each column of the codeset. For the reordered codeset it is assumed that all users are transmitting a 1 for the data and, therefore, one can sum each column to determine that the transmitted waveform is:

tx_waveform_reordered_code =[0 0 0 0 8 0 0 0].

Next, examine the same conditions for the reordered codeset, with inversion, and the results are as follows:

tx_waveform_reordered_code_w_inversion =[2 2 -6 2 2 2 2 2].

Note that while no attempt was made to optimize the example inversion code that was shown here, the peak of the transmitted signal is reduced from 8 to 6 (only the magnitude is of interest). While this case appears to give but a slight improvement, when operating with codesets of size 128 the peak can be reduced from 128 to approximately 75. This beneficially allows operation with correlated data without clipping.

It is expected that the RBU 12 of Fig. 1 will have an ability to generate the reordered (and possibly inverted) codes as shown in Figs. 3A-3C, 4 and 5, and to then assign one or more reordered codes to a SU 14 that requires a code or codes to communicate with the system. For example, the RBU controller 12e may be responsible for generating and assigning the reordered codes. Alternatively, the codes may be reordered at another location and then simply assigned by the RBU controller 12e to requesting ones of the SUs 14.

While the invention has been particularly shown and described with respect to preferred embodiments thereof, it

CLAIMS

What is claimed is:

1. A method for improving the spectral properties of a PN codeset for use in a synchronous CDMA communications system, comprising steps of:

providing a PN codeset matrix; and

reordering the columns of the PN codeset matrix by exchanging columns in accordance with a reordering code.

2. A method as in claim 1, and further comprising the step of inverting at least one codeword of the reordered PN codeset.

3. A method as in claim 1, and further comprising the step of selecting PN codes to optimize a subset of channels to operate in an asynchronous manner.

4. A synchronous CDMA communications system, comprising:

a radio base unit capable of bidirectional wireless communications with a plurality of subscriber units; and

a controller for reordering columns of a Hadamard codeset matrix by exchanging columns in accordance with a predetermined reordering code to produce a reordered pseudonoise (PN) codeset having improved spectral properties, and for assigning individual ones of the reordered PN codeset to requesting ones of the subscriber units.

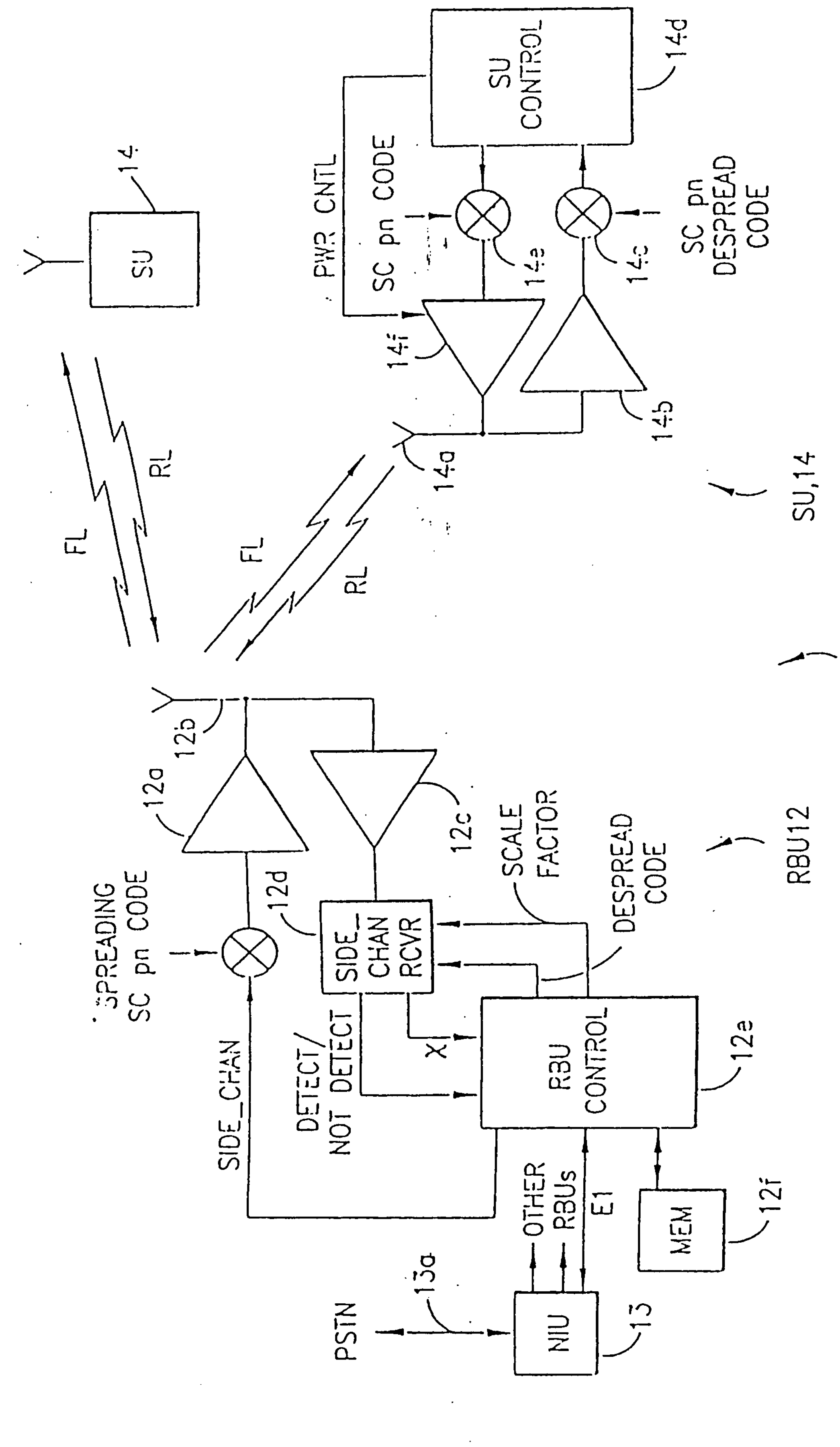
SU
14
SU CONTROL
14d
PWR CNTL
SC pn CODE
14e
SC pn DESPREAD CODE
14c
14f
14b
14a
FL
RL
FL
RL
SU,14
10
12b
12a
12c
SPREADING SC pn CODE
12d
SIDE_ CHAN RCVR
SCALE FACTOR
DESPREAD CODE
RBU12
SIDE_CHAN
DETECT/ NOT DETECT
X
RBU CONTROL
12e
OTHER RBUs
E1
MEM
12f
PSTN
13a
NIU
13

FIG.1

$$H_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

FIG. 3A

$$\mathrm{RC} = [3 \quad 1 \quad 2 \quad 4]$$

FIG. 3B

$$\mathrm{RH}_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ -1 & 1 & 1 & -1 \\ -1 & 1 & -1 & 1 \end{bmatrix}$$

FIG. 3C

$$Inversion\_pattern = \begin{bmatrix} 1 \\ 1 \\ -1 \\ 1 \\ -1 \\ 1 \\ -1 \\ 1 \end{bmatrix}$$

$$Reordered\_code\_w\_inversion = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & 1 & 1 & -1 & -1 & -1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\ -1 & 1 & -1 & -1 & 1 & 1 & 1 & -1 \\ -1 & 1 & -1 & 1 & -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & -1 & 1 & 1 & -1 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ -1 & -1 & -1 & 1 & 1 & -1 & 1 & 1 \end{bmatrix}$$

FIG. 5

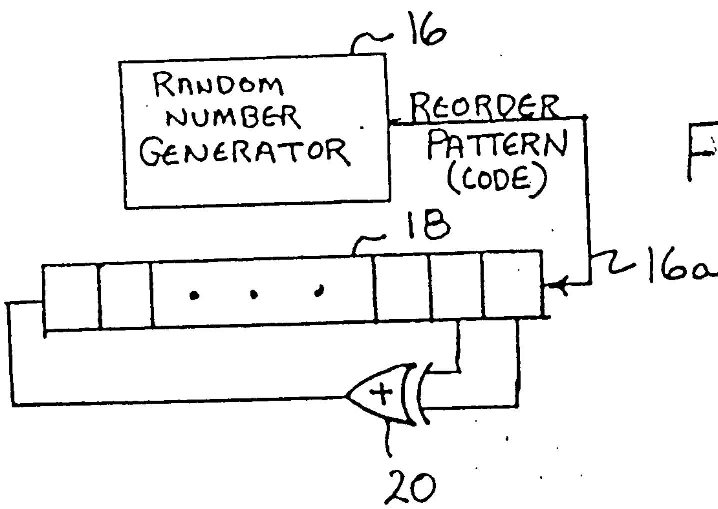

FIG. 6

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

370/335, 342, 209; 375/200, 206, 208, 209; 708/250, 252, 400, 410

CORRECTED VERSION*

PCT

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A method for improving the spectral properties of a PN codeset for use in channels of a synchronous CDMA telecommunications system. The method includes steps of (a) providing a PN codeset matrix; and (b) reordering the columns of the PN codeset matrix in accordance with a reordering code. The method may further include the step of inverting at least one code word of the reordered PN codeset in accordance with an inversion pattern, and may further include the step of selecting PN codes to optimize a subset of channels to operate in an asynchronous manner.

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WO 00/01091 A1

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Within the reordered Walsh set the codes have different auto-correlation and cross-correlation properties. In synchronous CDMA systems there may exist an asynchronous channel (e.g., the side channel) to synchronize users who are new to the system, or those that have lost

Describing the invention now in further detail, Fig. 3A illustrates an exemplary Hadamard matrix (treating a -1 as a 0). In this regard it is noted that corresponding values stored in a memory have binary values of 1 and 0. These bits are exclusive ORed to create a 0 or 1 chip value in each chip period. It is then assumed that in the subsequent modulation stage(s) the 0 and 1 values chips are remapped to -1 and +1 valued chips.

In accordance with this invention, reordered Hadamard codes are constructed by reordering the columns of the Hadamard matrix. For example, the Hadamard matrix (H) of Fig. 3A is reordered using the Reordering Code (RC) shown in Fig. 3B, and the resulting Reordered Hadamard (RH) code matrix is shown in Fig. 3C. Note that the third column has been moved to the first column position, and columns 1 and 2 have been shifted to the right by one column position.

In this case the Reordered Hadamard becomes a time shifted Hadamard with the codes renumbered. However, for Hadamards of order 8 or higher the reordering produces completely different codesets. To generate Reordering Codes, the states of an m-sequence generator can be lengthened by placing 128 at the end of the code. Randomly generated Reordering Codes can be employed as well. For example, Fig. 6 shows a block diagram of a random number generator 16 that outputs a Reordering Pattern or Code 16a to a shift register 18 having feedback through an XOR function 20.

Examining Fig. 3C it can readily be seen that one important advantage of the use of reordered Hadamard codes, in accordance with the teachings of this invention, is that all of the codes, except the all ones code, are perfectly balanced.

If all of the transmitted signals in the CDMA system need

For a case where all of the channels in the system 10 may be transmitting the same data (e.g., a sync pattern at the beginning of a frame), the resulting waveform is the sum of each column of the codeset. For the reordered codeset it is assumed that all users are transmitting a 1 for the data and, therefore, one can sum each column to determine that the transmitted waveform is:

tx_waveform_reordered_code =[0 0 0 0 8 0 0 0].

Next, examine the same conditions for the reordered codeset, with inversion, and the results are as follows:

tx_waveform_reordered_code_w_inversion =[2 2 -6 2 2 2 2 2].

Note that while no attempt was made to optimize the example inversion code that was shown here, the peak of the transmitted signal is reduced from 8 to 6 (only the magnitude is of interest). While this case appears to give but a slight improvement, when operating with codesets of size 128 the peak can be reduced from 128 to approximately 75. This beneficially allows operation with correlated data without clipping.

It is expected that the RBU 12 of Fig. 1 will have an ability to generate the reordered (and possibly inverted) codes as shown in Figs. 3A-3C, 4 and 5, and to then assign one or more reordered codes to a SU 14 that requires a code or codes to communicate with the system. For example, the RBU controller 12e may be responsible for generating and assigning the reordered codes. Alternatively, the codes may be reordered at another location and then simply assigned by the RBU controller 12e to requesting ones of the SUs 14.

While the invention has been particularly shown and described with respect to preferred embodiments thereof, it

CLAIMS

What is claimed is:

1. A method for improving the spectral properties of a PN codeset for use in a synchronous CDMA communications system, comprising steps of:

providing a PN codeset matrix; and

reordering the columns of the PN codeset matrix by exchanging columns in accordance with a reordering code.

2. A method as in claim 1, and further comprising the step of inverting at least one codeword of the reordered PN codeset.

3. A method as in claim 1, and further comprising the step of selecting PN codes to optimize a subset of channels to operate in an asynchronous manner.

4. A synchronous CDMA communications system, comprising:

a radio base unit capable of bidirectional wireless communications with a plurality of subscriber units; and

a controller for reordering columns of a Hadamard codeset matrix by exchanging columns in accordance with a predetermined reordering code to produce a reordered pseudonoise (PN) codeset having improved spectral properties, and for assigning individual ones of the reordered PN codeset to requesting ones of the subscriber units.

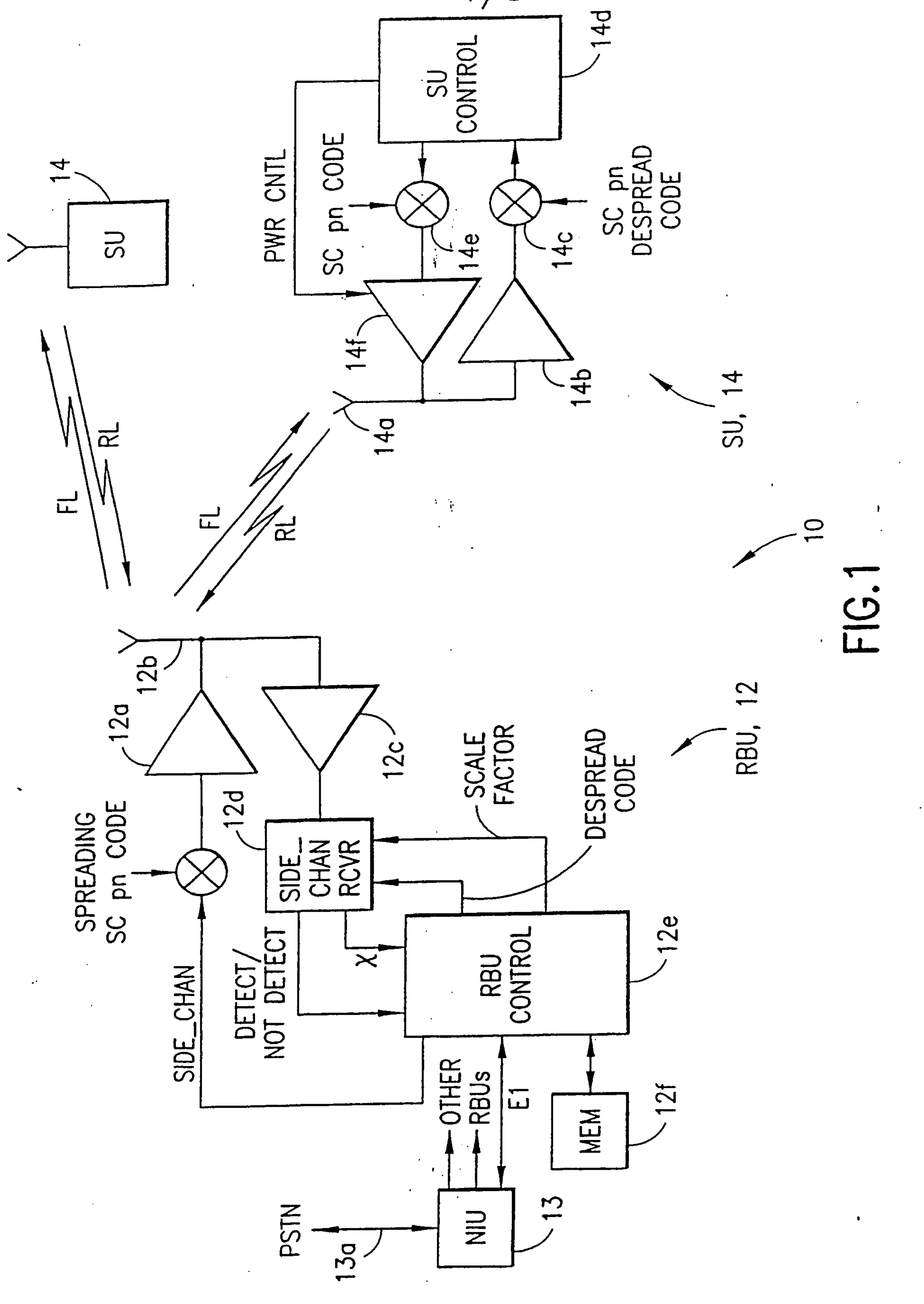
SU
14
SU CONTROL
14d
PWR CNTL
SC pn CODE
14e
14c
SC pn DESPREAD CODE
14f
14b
14a
SU, 14
FL
RL
FL
RL
10
12a
12b
12c
12d
SPREADING SC pn CODE
SIDE_ CHAN RCVR
SCALE FACTOR
DESPREAD CODE
RBU, 12
SIDE_CHAN
DETECT/ NOT DETECT
X
RBU CONTROL
12e
OTHER RBUs
E1
MEM
12f
PSTN
13a
NIU
13

FIG.1

$$H_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

FIG.3A

$$RC = [3 \quad 1 \quad 2 \quad 4]$$

FIG.3B

$$RH_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ -1 & 1 & 1 & -1 \\ -1 & 1 & -1 & 1 \end{bmatrix}$$

FIG.3C

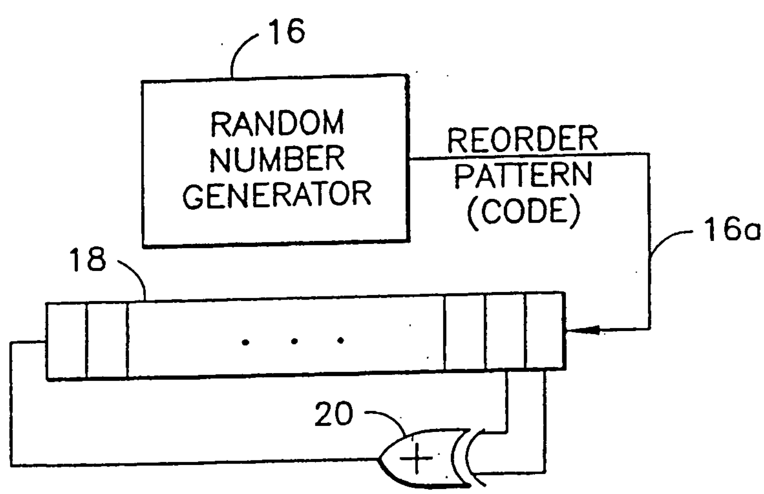

FIG.6

$$\mathit{Inversion\_pattern}=\begin{bmatrix}1\\1\\-1\\1\\-1\\1\\-1\\1\end{bmatrix}$$

$$\mathit{Reordered\_code\_w\_inversion}=\begin{bmatrix}1&1&1&1&1&1&1&1\\1&1&-1&1&1&-1&-1&-1\\1&-1&-1&1&-1&1&1&-1\\-1&1&-1&-1&1&1&1&-1\\-1&1&-1&1&-1&1&-1&1\\1&-1&-1&-1&1&1&-1&1\\1&1&-1&-1&-1&-1&1&1\\-1&-1&-1&1&1&-1&1&1\end{bmatrix}$$

FIG.5

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

370/335, 342, 209; 375/200, 206, 208, 209; 708/250, 252, 400, 410

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